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In-season forecast for Atlantic salmon (*Salmo salar* L.) returning to Campbellton River in 1998

by

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ABSTRACT

This document summarizes techniques used for in-season forecasts of Atlantic salmon returning to Campbellton River in 1998. Three techniques were examined: proportional, simple regression and regression with environmental correction. Data is limited to six years, 1993-98, of complete adult counts at a counting fence. The low degrees of freedom may have contributed to the high correlations. Regression with environmental correction gave the most accurate forecasts with a standard error of less than 10% of the forecasted value. While thermal habitat was used as an environmental variable in the regression model to good effect, there are other climate data that could also be used.

RÉSUMÉ

Ce document résume les techniques utilisées pour les prévisions, en cours de saison, des remontes de saumon de l'Atlantique dans la rivière Campbellton en 1998. Trois techniques ont été examinées : proportionnelle, régression simple et régression avec correction environnementale. Les données sont limitées à six années, 1993-1998, de dénombrements complets d'adultes à une barrière de dénombrement. Les faibles degrés de liberté peuvent avoir contribué au niveau élevé de corrélation. La régression avec correction environnementale a donné les prévisions les plus exactes avec une marge d'erreur normale de moins de 10 % de la valeur prévue. Bien que la température de l'habitat ait été utilisée avec succès comme variable environnementale dans le modèle de régression, d'autres données climatiques pourraient être utilisées également.

INTRODUCTION

In-season forecasts of Atlantic salmon returns to individual rivers have been provided to fisheries managers in Newfoundland since 1990. In-season forecasts are typically based on cumulative counts to a specific date to a counting facility adjusted in some way to predict or forecast the total count at the end of the season. There are several techniques for in-season forecasts, one of the simplest is to divide the current-year count by the proportion to the same date from other years or an average of data for other years. Another method is to generate in-season forecasts from regressions of counts to date versus total count to the end of the year (Dempson et al. 1998; Harvie & Amiro 1998). Other variables, such as those influencing run timing, can also be included in this approach as shown by Harvie & Amiro for climate data (1998). In-season forecasts are used by fisheries managers to make in-season adjustments to fishing plans in order to achieve management objectives based on maintaining some level of spawning escapement for conservation purposes. At the assessment meetings in 1998, it was decided to review the techniques used as well as their accuracy and precision in order to standardize and improve them. The purpose of this paper is to review methodology used to provide in-season forecasts and estimates of returns to the counting fence at Campbellton River.

METHODS

Two techniques of forecasting in-season salmon returns are examined for Campbellton River salmon. The first technique, labelled the proportional technique, forecasts returns in a given year from the proportional distribution of returns in an average series of years applied to the current year count to the same date. The second technique examines regressions of count to date on end of season count to provide an in-season forecast of returns. Environmental parameters are examined for their potential in improving accuracy of the forecasts by inclusion in the regression technique. Data from 1998 are used as an example of how the techniques might be applied in a specific year.

Sources of data

A counting fence for upstream migrating salmon has been operated every year since 1993 on Campbellton River (Downton & Reddin 1998). The counting fence and counting procedures carried out with an underwater video camera have been fully described in Downton & Reddin (1998). Since there have been no washouts or other problems that would result in incomplete counts and because there are no legal removals in the short distance from the counting fence to the sea, the counts described herein are considered an accurate measure of the total number of salmon entering Campbellton River exclusive of poaching. The daily count data was summed into standard weeks with the first week being that week which ends on June 7. This week was chosen so that forecasted returns would be as complete as possible for managers at the first of each week and would change annually.

In-season forecasts

In-season forecasts of small salmon returns to Campbellton River were generated from regressions of counts to date versus total count for the year, following an approach by Dempson et al. (1998). The count less an expectation of angling catches or other removals is then an estimate of spawning escapement which can be compared with the desired conservation requirements for the river or some other management goal. In total, five years of data (1993-97) were available. In-season dates chosen were the standard dates described above. In order for an in-season forecast to be useful to managers, the forecast must be provided in a timely fashion so that fisheries can be adjusted either upward or downward depending on the circumstances. The further into the season before making an in-season forecast the less useful any management action becomes because a higher proportion of removals by angling will have already taken place.

A retrospective analysis examining the predicted value versus the actual one was used to determine the accuracy of the forecasts. The 1998 data were not included directly in the regression analysis so as to provide an example of how the method works in the current year.

Environmental parameters

The accuracy and precision of any in-season forecast degrades due to variability in annual run timing. Variability in run timing is thought to be mainly under environmental control (Narayanan et al. 1995; Harvie & Amiro 1998). If run timing could be accurately predicted then more accurate forecasts could be made and then fisheries adjusted accordingly. Several authors have demonstrated that water temperature, presence of ice and amount can delay entry of salmon into freshwater (Reddin & Shearer 1987; Narayanan et al. 1995). Several environmental parameters have been examined for their usefulness in determining whether runs were going to be early or late (Drinkwater et al. 1998). One such parameter is thermal habitat, a measure of ocean suitability for salmon growth and survival in the northwest Atlantic (Reddin & Friedland 1993). The thermal habitat data used was the sum of monthly values for April and May. In order for the resulting forecast to be useful to fish management, I assumed that the chosen regression model must provide a forecast of end of season count at the earliest possible date while maintaining a standard error (bias) of the estimate of, at most, one-tenth of the 1993-98 average end of season count of small salmon (Harvie & Amiro 1998). For this analysis, the entire dataset including 1998 was used in the regressions. Even so there is only six years of data for model building and testing which may lead to overspecification of model parameters and artificially high coefficient of determinations.

RESULTS

The daily run timing of small salmon to Campbellton River varies considerably from year to year as shown by the daily counts at the counting fence (Table 1 and Fig. 1). Variability in run timing is shown with up to an 11 day difference in the 25th percentile

and a 12 day difference in the 75th percentile of small salmon returns to the counting fence (Fig. 2a). Median dates were later in 1994 and 1997 than in 1996 and 1998 which was the earliest on record. The length of the season also varies from year to year as shown by the magnitude of the difference between the 25th and 75th percentiles or the 10th and 90th percentiles. The 1997 run was the longest on record while the 1998 run was one of the shortest.

Smolt run timing is also variable with most of the variation occurring in the last three years (Fig. 2b). Variability of the smolt run is apparent with up to a 15 day difference in the 25th percentile and a 14 day difference in the 75th percentile. Median dates were later in 1997 and earliest in 1996 and 1998. The length of the run also varies from year to year as shown by the magnitude of the difference between the 25th and 75th and 10th and 90th percentiles. The 1996 run was the longest on record while the 1997 run was the shortest.

Survival data from smolt to adult is also available for Campbellton River salmon as both smolts and adult returning salmon are counted (Downton & Reddin 1998). Examination of the relationship between survival and adult run timing and smolt and adult run timing indicated that neither were significantly correlated at the 5% level of significance. For survival and adult run timing the correlation coefficient(Spearman r) was 0.39 with degrees of freedom (df) of 3 and for smolt and adult run timing the correlation coefficient (Spearman) was 0.79 with df of 4. This is a very short time series and it would be inappropriate to be overly conclusive as these results may change as a longer time series becomes available.

Figure 3 illustrates the sequential regressions of in-season counts to various dates with the corresponding total run for the year beginning with June 7 (week 1) and progressing to July 26 (week 8). The first week with a reasonable relationship between total count and in-season count is week 5 with an R^2 of 0.55 at which time 57% (range of 31% in 1994 and 72% in 1996) of the small salmon on average had entered the system. The next week which is week 6 (July 6-12) has a much improved R^2 of 0.90 which increases to 0.93 in week 7 and 0.99 in week 8. Therefore, it would appear possible to provide a fairly accurate in-season forecast for Campbellton River adult returns by July 5. Since about 60% of the run had entered the river by July 5 leaves enough time for fisheries managers to make changes to fishing plans if warranted.

Residuals from the sequential regressions indicate a trend to increasing negative residuals in the last few years for weeks 4, 5 and 6 (Fig. 4). For 1998, the forecast is about 1,250 fish higher in week 4 and almost 1,000 fish higher in week 5 than the actual values. The residual pattern also declines with time for week 6 but with lower residuals in recent years. For 1998, the forecast is about 150 fish higher than the actual value. For weeks 6 and 7, the residual pattern is erratic from year to year with no trend. For 1998, forecasts for week 7 are only 200 fish too high and about 70 in week 8.

If expressed as a percentage of the actual value then residuals for week 5 are the highest at about 30% declining to about 5% for week 6, 6% for week 7, and 3% for week 8 (Fig. 5). All were negative except those for week 8. The negative residuals indicate an over-

forecast of returns suggesting that management decisions based on these forecasts might tend to forestall action when it was actually warranted.

Comparison of residuals from linear regression and proportional forecasts demonstrates that linear forecasts are more accurate than proportional forecasts (Fig. 6). Linear forecasts were consistently better than proportional for all weeks from week 1 to week 6. The residual pattern for the proportional method shows much large residuals in the warm years, viz. 1996 and 1998 than in the colder years viz. 1993-94 and 1997. This is not the case with the linear method which shows a pattern of increasing residuals with time and not an abrupt shift to higher residuals in 1998 only. Forecasts for 1998 returns are much better for the linear than the proportional method.

The addition of an environmental parameter into the regression technique also seems to improve the forecasted values. The coefficient of determination for weeks 1 to 6 regressions with no environmental parameter ranged from 0.02 to 0.90 and with an environmental parameter, in this case thermal habitat, range from 0.57 in week 2 to 0.99 in week 6. Also comparison of the predicted versus observed values indicates that under-forecasting is more common than over-forecasting returns (Fig. 7A). All regressions for weeks 1 to 6, averaged over the 1993-98 period, maintained a very acceptable standard error of the regression estimate (Fig. 7B). When expressed as a percent of the standard error of the forecasted value it was always less than 15%. A note of caution is required here due to the small sample size. The Campbellton River counting fence has only been operated for six years and additional data may alter the relationship between variables and hence the precision of the estimated number of salmon returns.

DISCUSSION

In-season reviews of salmon abundance have been done annually in Newfoundland and Labrador since about 1990. In some cases, the reviews have resulted in alterations to fishing plans and openings or closures of angling in some rivers. An example of the alteration of fishing plans due to an in-season review occurred in 1997 in insular Newfoundland (O'Connell et al. 1998). It was shown during in-season review that many rivers were not going to achieve conservation requirements without some alteration to fishing plans to reduce potential catches. As a result most rivers were closed to angling in mid-July and remained that way to the end of the fishing season (O'Connell et al. 1998).

Although in-season reviews of fish abundance are common in several jurisdictions, little is available in the literature describing the techniques and accuracy of the results. A couple of exceptions are Dempson et al. (1998) and Harvie & Amiro (1998). Harvie & Amiro (1998) stated that in order to be useful to managers forecasted values should maintain a standard error of the estimate of, at most, 25% of average values. Forecasts shown herein for Campbellton River adult salmon returns after week 6 show standard errors that are consistently less than 15% of the estimates. Harvie & Amiro (1998) further demonstrated that inclusion of environmental parameters in the predictive

relationship greatly improved the forecasts which was also the case for Campbellton River. In my paper, I have shown that:

- Regression technique performs better than proportional techniques;
- Inclusion of an environmental variable improves accuracy considerably;
- In-season reviews for other systems should consider testing the regression technique to see if it leads to improvement in forecasts. Similarly, inclusion of an environmental variable may also help to improve forecasts by acting as a predictor of run timing.
- Run timing variability if not accounted for will degrade forecasts in years with very early or late runs compared to average. While the forecasts may still work most of the time, inclusion of an environmental parameter in the regression may improve forecasts considerably.

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Table 1. Campbellton River upstream migration of adult salmon through the counting fence from 1993 to 1998.

	1993			1994			1995			1996			1997			1998		
Date	Grilse	accum total	Large salmon	Grilse	accum total	Large salmon	accum total	Grilse	accum total	Large salmon	accum total	Grilse	accum total	Large salmon	accum total	Grilse	accum total	Large salmon	accum total
02-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-Jun	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
06-Jun	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
07-Jun	0	0	0	0	0	0	0	0	0	0	0	4	6	1	2	0	0	0	0
08-Jun	0	0	0	0	0	0	0	0	0	0	0	8	14	0	2	0	0	0	0
09-Jun	0	0	0	0	0	0	0	0	0	0	0	14	28	2	5	0	0	0	0
10-Jun	0	0	0	0	0	0	0	0	0	0	0	13	33	4	9	0	0	0	0
11-Jun	0	0	0	0	0	0	0	0	0	0	0	21	54	1	10	0	0	0	0
12-Jun	0	0	0	0	0	0	0	0	0	0	0	28	82	5	15	0	0	0	0
13-Jun	4	4	0	0	0	0	0	0	0	0	0	35	117	6	21	0	0	0	0
14-Jun	0	4	0	0	0	0	0	0	0	0	0	0	117	0	21	0	0	0	0
15-Jun	4	8	0	0	0	0	0	1	1	1	1	114	249	5	26	3	3	2	4
16-Jun	0	8	0	0	0	0	0	1	2	0	1	114	363	20	46	7	10	0	4
17-Jun	5	14	0	0	0	0	0	2	4	1	2	73	436	5	51	8	18	2	6
18-Jun	3	17	0	0	1	4	0	0	4	12	0	2	129	567	7	58	12	28	2	8
19-Jun	0	25	0	0	10	14	4	4	6	18	1	3	37	604	1	59	15	43	1	9
20-Jun	8	33	0	0	17	31	1	5	45	63	7	10	164	768	18	77	19	62	0	9
21-Jun	0	33	0	0	0	31	0	5	0	63	0	10	0	768	0	77	0	62	0	9
22-Jun	39	77	3	3	39	69	3	8	31	183	1	10	81	934	15	96	38	183	2	15
23-Jun	50	127	0	3	38	97	3	11	52	341	5	23	94	1028	8	104	88	229	4	19
24-Jun	106	233	3	6	140	237	17	28	86	386	7	30	139	1167	4	108	104	333	3	22
25-Jun	180	334	0	6	119	306	7	35	193	479	9	39	150	1317	13	115	81	414	1	23
26-Jun	191	525	3	9	78	434	1	36	53	482	1	40	107	1424	6	125	77	411	1	24
27-Jun	44	569	0	9	93	536	1	37	248	730	9	49	43	1467	9	134	48	459	3	27
28-Jun	0	569	0	9	0	536	0	37	0	730	0	49	0	1467	0	134	0	459	0	27
29-Jun	172	824	12	28	72	670	0	37	119	943	3	56	66	1625	14	154	82	688	1	33
30-Jun	136	960	7	35	64	722	1	38	85	1028	1	57	166	1791	16	170	91	730	0	33
01-Jul	394	1256	11	46	40	762	1	39	145	1193	3	60	113	1904	35	205	47	783	1	34
02-Jul	279	1535	11	58	31	797	0	39	109	1302	4	64	149	2053	21	226	36	819	0	34
03-Jul	234	1767	5	63	10	807	0	39	71	1373	1	65	103	2156	26	252	60	887	0	34
04-Jul	200	1967	9	72	40	847	0	39	170	1543	3	68	84	2240	20	272	45	929	0	34
05-Jul	0	1967	0	72	0	847	0	39	0	1543	0	68	0	2240	0	272	0	929	0	34
06-Jul	283	2343	9	81	145	1042	7	47	194	1790	2	71	67	2373	19	317	43	1008	0	34
07-Jul	137	2479	3	88	343	1385	9	56	68	1810	1	72	115	2488	29	346	30	1045	1	35
08-Jul	136	2685	3	88	98	1483	5	61	68	1886	1	73	61	2549	20	366	22	1067	0	35
09-Jul	102	2787	3	91	88	1571	4	65	27	1913	1	74	31	2580	7	373	18	1085	2	37
10-Jul	143	2872	3	94	20	1689	2	67	40	1953	0	74	83	2663	11	384	11	1096	1	38
11-Jul	100	2972	2	96	66	1675	3	70	65	2018	0	74	53	2715	16	400	17	1113	1	39
12-Jul	0	2972	0	96	0	1675	0	70	0	2018	0	74	0	2715	0	400	0	1113	0	39
13-Jul	119	3190	5	101	41	1796	0	73	21	2115	0	75	21	2764	0	413	9	1130	1	40
14-Jul	69	3259	2	107	36	1882	2	75	27	2152	1	76	182	2946	52	464	7	1145	0	40
15-Jul	72	3333	4	113	34	1886	1	76	13	2165	1	77	62	2980	20	484	26	1150	14	54
16-Jul	1	3333	0	113	26	1862	3	79	75	2240	9	86	10	2990	7	491	11	1191	4	58
17-Jul	77	3410	3	116	41	1903	1	80	106	2346	13	99	14	3012	6	497	8	1197	0	58
18-Jul	106	3516	5	121	3	1906	0	80	77	2423	8	106	21	3033	11	510	5	1202	0	58
19-Jul	0	3516	0	121	0	1906	0	80	0	2423	0	106	0	3033	0	510	0	1202	0	58
20-Jul	34	3625	0	133	34	1946	1	82	43	2513	3	110	6	3058	4	521	4	1208	2	61
21-Jul	19	3644	0	133	53	1999	0	90	29	2542	1	111	5	3063	3	524	10	1218	2	63
22-Jul	28	3671	2	135	52	2051	5	95	17	2559	1	112	18	3081	6	530	4	1222	1	64
23-Jul	68	3712	3	138	150	2201	12	107	23	2584	1	113	4	3085	3	533	62	1284	7	71
24-Jul	39	3751	3	141	268	2469	10	125	41	2625	1	114	9	3094	1	534	55	1339	19	90
25-Jul	31	3782	1	142	53	2522	7	132	82	2707	15	129	12	3106	1	535	13	1352	5	95
26-Jul	0	3782	0	142	0	2522	0	132	0	2707	0	129	0	3106	0	535	0	1352	0	95
27-Jul	14	3810	0	132	15	2571	4	140	36	2797	6	142	13	3136	4	541	13	1399	5	113
28-Jul	12	3822	0	132	10	2581	0	140	41	2838	11	153	13	3139	4	545	1	1400	1	114
29-Jul	5	3827	0	132	8	2589	2	142	18	2856	4	157	11	3150	5	550	2	1402	1	115
30-Jul	6	3833	0	132	12	2601	1	143	10	2866	3	160	13	3163	2	552	6	1408	2	117
31-Jul	12	3845	0	132	7	2608	1	144	9	2874	1	161	4	3166	0	552	8	1413	4	121
01-Aug	8	3853	0	132	4	2612	1	145	13	2887	2	163	6	3172	1	553	1	1414	0	121
02-Aug	8	3861	0	132	42	2654	7	160	24	2911	12	179	3	3182	0	556	1	1417	0	121
03-Aug	17	3878	0	132	6	2701	0	160	18	2929	1	180	3	3185	0	556	1	1418	1	122
04-Aug	2	3880	0	132	6	2707	0	160	3	2932	0	180	2	3187	0	556	2	1420	2	124
05-Aug	9	3889	0	132	32	2739	6	166	3	2935	1	181	1	3188	0	556	5	1425	0	124
06-Aug	11	3900	0	132	32	2771	7	173	14	2951	13	194	0	3188	0	556	3	1428	1	125
07-Aug	5	3911	1	134	6	2797	1	174	10	2961	9	203	2	3190	1	557	2	1430	0	125
08-Aug	7	3932	0	137	6	2806	1	175	1	2966	0	203	2	3195	1	558	1	1433	0	125
09-Aug	4	3936	0	137	8	2814	2	177	6	2972	0	203	0	3195	0	558	0	1433	0	125
10-Aug	3	3939	0	137	7	2821	0	177	1	2973	0	203	2	3197	1	559	5	1438	1	126
11-Aug	7	3946	0	137	1	2822	1	178	3	2976	1	204	1	3198	0	559	54	1492	46	172
12-Aug	1	3947	0	137	2	2824	1	179	3	2979	4	208	1	3199	0	559	19	1511	7	179
13-Aug	0	3947	0	137	0	2824	0	179	0	2979	0	208	0	3199	0	559	0	1511	0	179
14-Aug	0	3947	0	137	0	2824	0	179	0	2979	0	208	0	3199	0	559	0	1511	0	179
15-Aug	8	3955	1	138	2	2826	0	179	27	3006	5	213	3	3202	0	559	14	1525	8	191
16-Aug	0	3955	0	138	0	2826	0	179	0	3006	0	213	0	3202	0	559	0	1525	0	191
17-Aug	3	3963	1	140	3	2833	0	180	4	3010	1	214	1	3205	0	559	21	1546	14	207
18-Aug	1	3964	0	140	1	2834	1	181	2	3012	0	214	3	3208	0	559	91	1640	23	230
19-Aug	0	3964	0	140	3	2837	3	184	1	3013	0	214	0	3208	1	560	58	1698	11	241
20-Aug	4	3968	0	140	3	2840	0	184	5	3018	0	214	0	3208	0	560	8	1706	0	241
21-Aug	3	3971	0	140	3	2843	0	184	3	3020	0	214	0	3208	0	560	3	1707	0	241
22-Aug	4	3975	1	141	1	2843	0	184	2	3022	1	215	0	3208	0	560	1	1708	0	241
23-Aug	0	3975	0	141	0	2843	0	184	0	3022	0	215	0	3208	0	560	0	1708	0	241
24-Aug	3	3981	0	141	2	2846	1	185	1	3029	2	218	0	3208	0	560	11	1724	9	251
25-Aug	0	3981	1	142	3	2849	0	185	2	3031	0	218	0	3208	0	560	2	1726	0	251
26-Aug	0	3981	0	142	1	2850	0	185	1	3032	0	218	0	3208	0	560	4	1730	1	252
27-Aug	3	3984	0	142	1	2851	1	186	3	3035	0	218	0	3208	0	560	37	1767	4	256
28-Aug	0	3984	0	142	0	2851	0	186	0	3035	0	218	0	3208	0	560	10	1787	1	257
29-Aug	1	3985	0	142	0	2851	0	186	0	3035	0	218	0	3208	0	560	2	1789	0	257
30-Aug	0	3985	0	142	0	2851	0	186	0	3035	0	218	0	3208	0	560	0	1789	0	257
31-Aug	1	3990	0	142	0	2852	0	187	0	3035	0	218	0	3208	0	560	122	1900	20	316
01-Sep	1	3991	0	142	0	2852	0	187	0	3035	0	218	0	3208	0	560	0	1900	0	316
02-Sep	2	3993	0	142	1	2853	1	188	0	3035	0	218	0	3208	0	560	2	1902	0	316
03-Sep	1	3994	0	142	0	2853	0	188	0	3035	0	218	0	3208	0	560	5	1907	1	317
04-Sep	3	3997	0	142	0	2853	0	188	0	3035	0	218	0	3208	0	560	4	1911	2	319
05-Sep	3	4000	2	144	0	2853	1	189	0	3035	0	218	0	3208	0	560	1	1912	1	320
06-Sep	1	4001	0	144	0	2853	0	189	0	3035	0	218	0	3208	0	560	0	1912	0	320
07-Sep	1	4002	0	145	1	2854	0	189	0	3035	0	218	0	3208	0	560	2	1914	1	321
08-Sep	0	4002	0	145	1	2855	0	189	0	3035	0	218	0	3208	0	560	1	1915	0	321
09-Sep	0	4002	0	145	0	2855	0	189	0	3035	0	218	0	3208	0	560	0	1915	0	321
10-Sep	0	4002	0	145	1	2856	1	190	0	3035	0	218	0	3208	0	560	0	1915	0	321
11-Sep	0	4002	0	145	0	2856	1	191	0	3035	0	218	0	3208	0	560	0	1915	0	321
12-Sep	0	4002	0	145	1	2857	0	191	0	3035	0	218	0	3208	0	560	0	1915	0	321
13-Sep	0	4002	0	145	0	2857	0	191	0	3035	0	218	0	3208	0	560	0	1915	0	321
Total	4002		145	2857		191	3035		218	3208		560	1915		321	3275		482	
Overall Total	6146			3048			3253			3768			2236			3677			

Fig. 1. Daily upstream migrating salmon counts for Campbellton River, 1993-98.

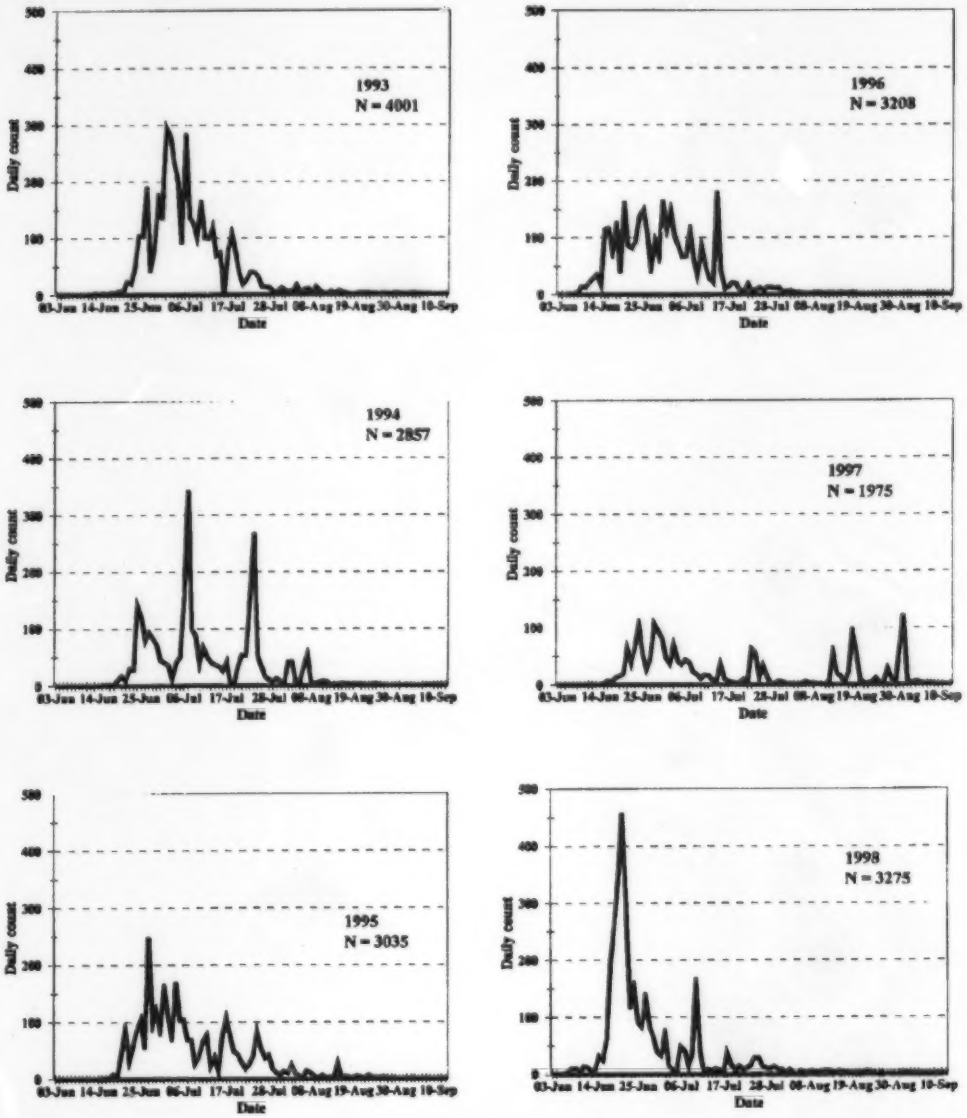

Fig. 2a. Annual variation in run timing for small salmon at Campbellton River, Nfld. Vertical lines represent the 10th and 90th percentiles of the day of the year of migration, the rectangle is the 25th and 75th percentiles, and the marker within the rectangle is the median run timing value.

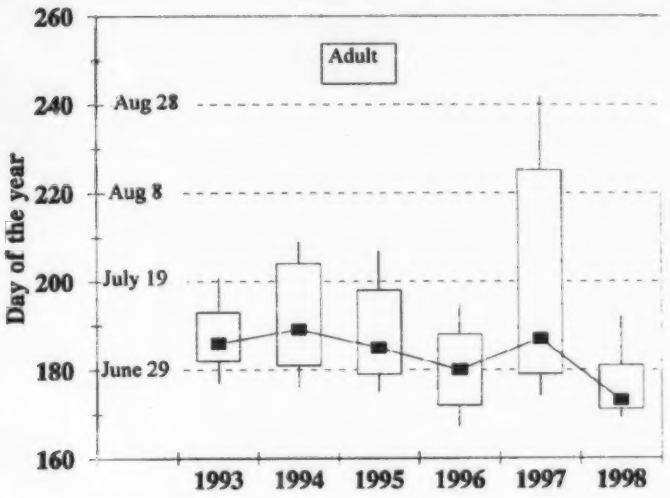

Fig. 2b. Annual variation in run timing for smolts at Campbellton River, Nfld. Vertical lines represent the 10th and 90th percentiles of the day of the year of migration, the rectangle is the 25th and 75th percentiles, and the marker within the rectangle is the median run timing value.

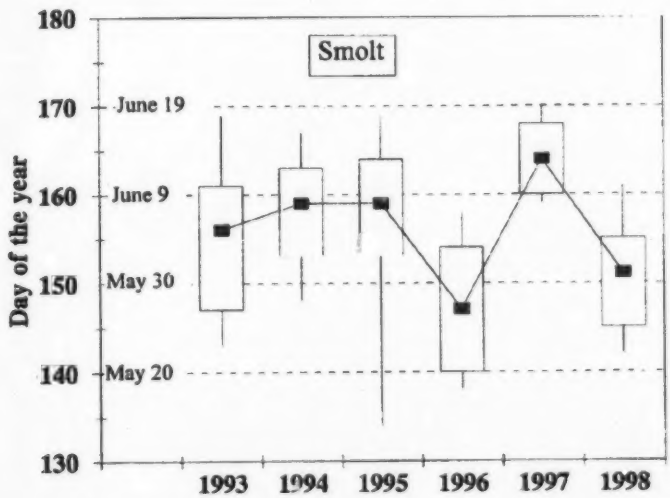

Fig 3. Relationships between count to end of season on count to the end of various weeks at Campbellton River, Newfoundland, 1993-97. 1998 value is shown for comparison.

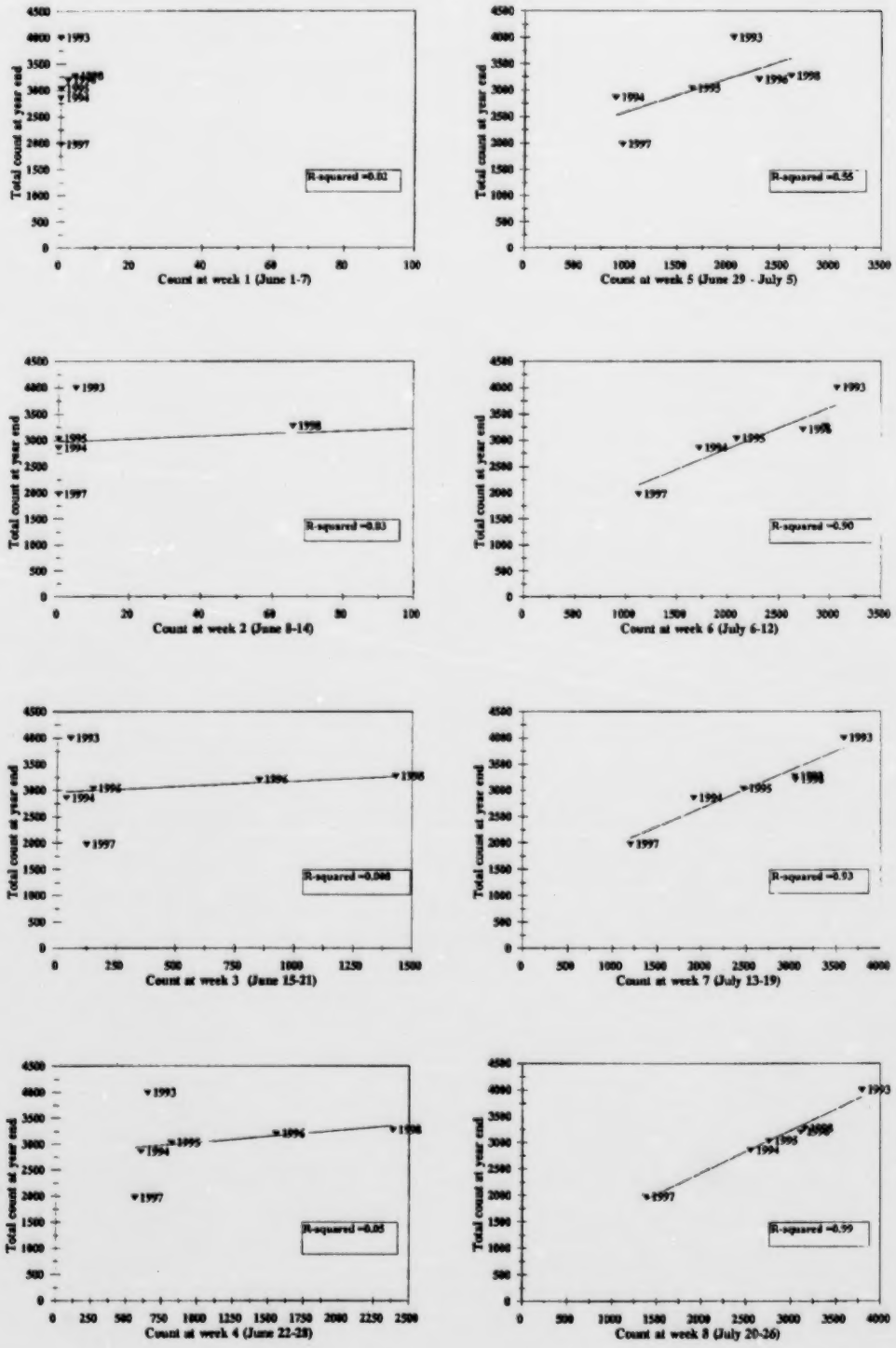
Total count at year end
Count at week 1 (June 1-7)
R-squared =0.01
Count at week 5 (June 29 - July 5)
R-squared =0.55
Count at week 2 (June 8-14)
R-squared =0.83
Count at week 6 (July 6-12)
R-squared =0.90
Count at week 3 (June 15-21)
R-squared =0.998
Count at week 7 (July 13-19)
R-squared =0.93
Count at week 4 (June 22-28)
R-squared =0.05
Count at week 8 (July 20-26)
R-squared =0.99

Fig 4. Residuals from regression of count to end of season on count to the end of the week.

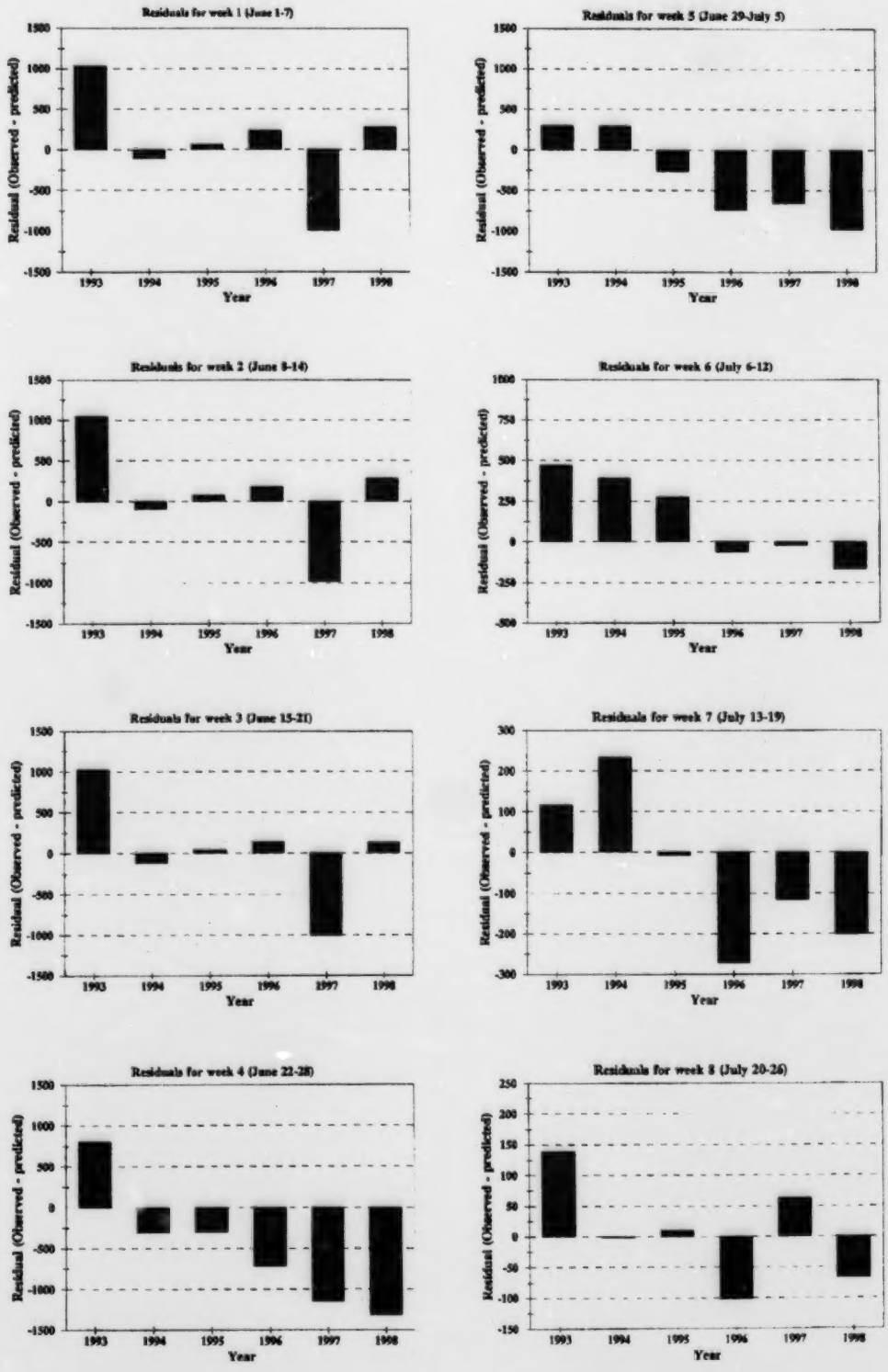

Fig 5. Comparison of the residual vs observed expressed as a percentage of the observed value.

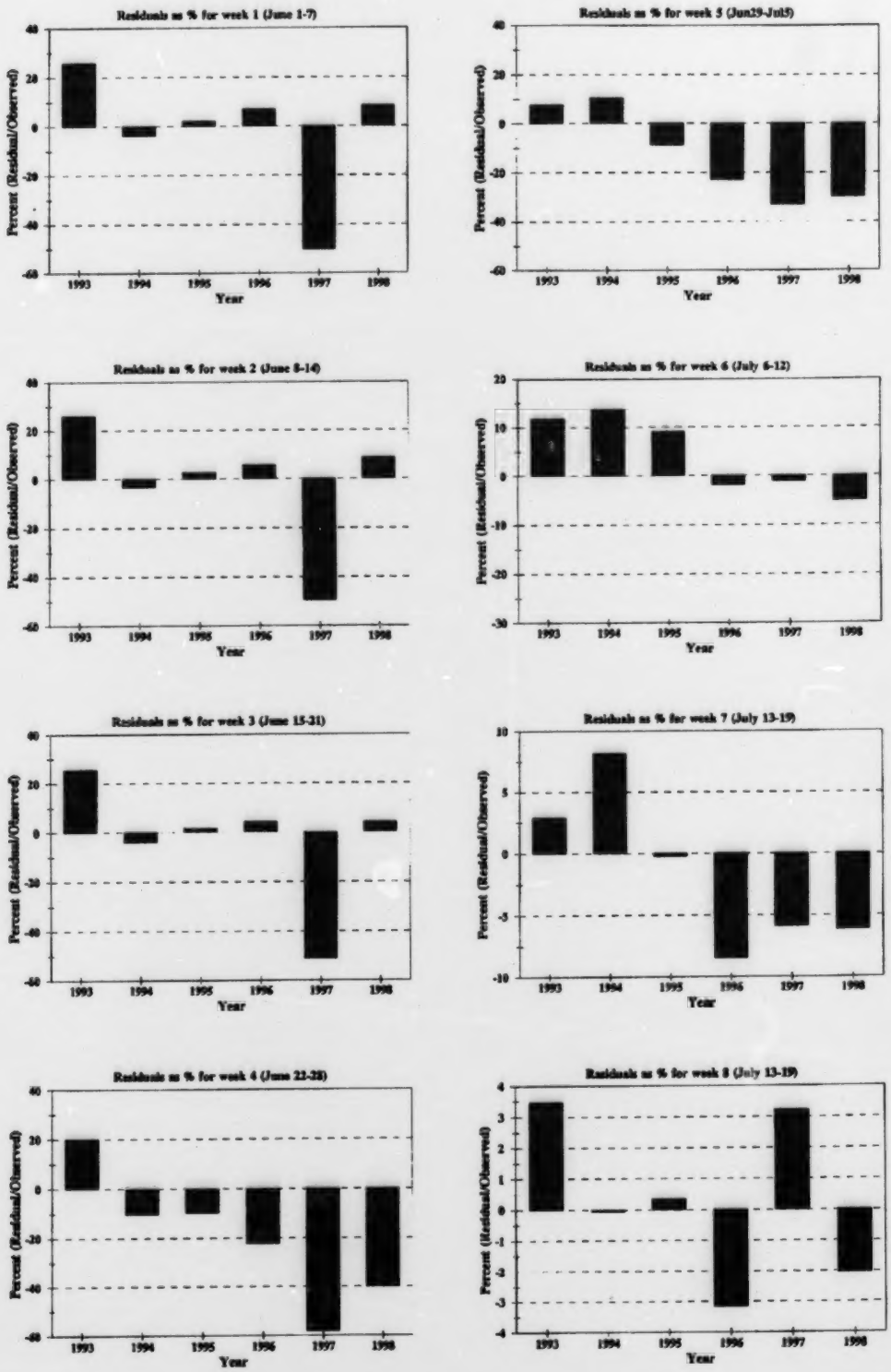
Residuals as % for week 1 (June 1-7)
Residuals as % for week 5 (Jun29-Jul5)
Residuals as % for week 2 (June 8-14)
Residuals as % for week 6 (July 6-12)
Residuals as % for week 3 (June 15-21)
Residuals as % for week 7 (July 13-19)
Residuals as % for week 4 (June 22-28)
Residuals as % for week 8 (July 13-19)
Percent (Residual/Observed)
Year
1993
1994
1995
1996
1997
1998

Fig. 6. Comparison of residual percents from forecasts based on linear (left side) and proportion (right side) methods for adults at Campbellton River, Nfld.

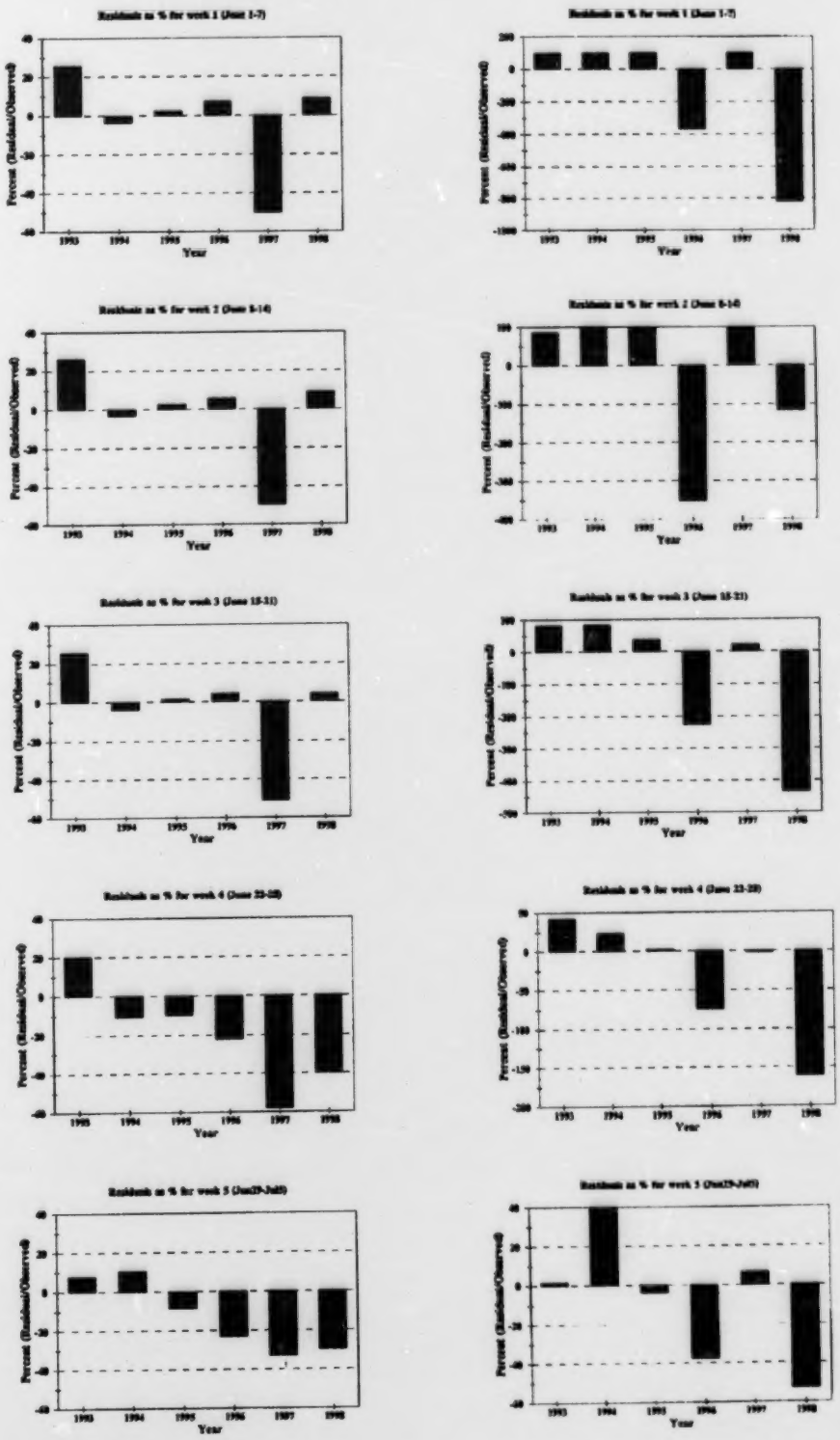

Fig. 7. A - is a comparison of end of season count on week 1 - 6 cumulative counts and thermal habitat. B - Average weekly (1993-98) standard error of the estimate in percent.